International Conference on Green Energy & Environmental Engineering (GEEE-2018)
Proceedings of Engineering and Technology – PET
Vol.37 pp.82-85

Contribution for Green Road Freight Transportation: Truck Platoon Application Based on Fuzzy Logic

S.moh ahmed[12*] said.hayat[1] ,Yassin El Hillali[2] , Atika Rivenq[2]
[1]IFSTTAR, Villeneuve d'Ascq Cedex,france
[2]UVHC, IEMN-DOAE Valenciennes, France
nomsaidahmed@gmail.com
Said.hayat@ifsttar.fr
yassin.elhillali@univ-valenciennes.fr
atika.menhaj@univ-valenciennes.fr
GIS-GRAISyHM and UVHC

Abstract

A simple, Truck platoon is the process of coupling two or more trucks together while they are travelling on a highway. Truck platoon increases the productivity of road transportation sector and truck industries, reduction of green road freight operational costs as a result of fuel saving, and significant reduction of its environmental hazard due to the accumulation of greenhouse gas (Carbon dioxide) from green road freight transportation. This paper seeks to provide a framework towards applying the theory of fuzzy logic to monitor the green driver behaviors so as to achieve fuel savings and emission reduction using driving assessment models. This paper also explains the conditions for effective drag reduction through controlling driver behaviors, its contribution to the green freight road transportation industries and sharing of information that are pertinent to transportationvia V2V/V2I connectivity Conclusion was drawn and recommendation based on the environmental and trucks platoon characteristics of the green driver concept were made

Keywords: Drag Reduction; Fuzzy Logic; Greenhouse Gas; Green road;Truck Platoon.

1. Introduction

Truck platooning is an extension of cooperative adaptive cruise control and the technology of forwarding collision avoidance which provides automated lateral and longitudinal vehicle control to maintain a tight formation of vehicles with short following distance. [1] This involves a situation whereby two or more trucks are driving in a closed manner with one after the other at high velocity. To obtain a significant fuel saving through increased aerodynamics and corresponding reduced emission, therefore it is suggested that there must be a small gap between the trucks so as to achieve this. Why do we need truck Platoon? Therefore, Truck platooning has great potential for reducing transport costs, by lowering fuel consumption due to improved aerodynamics from reduction of air resistance, eliminating the need for an attentive driver in the second vehicle, and better usage of truck assets, by maximization of driving times and lowering of idle time. On the societal level, driving safety increases as typically 90% of all accidents are human-induced, and platooning technology prevents human errors, leading to lower rate of accidents and damages. Greenhouse gas and air quality related emissions decrease, and congestion and traffic jams are also being reduced. This current study aims to find a new approach for the green driver behaviors, towards achieving fuel saving and emission reduction as a function coordinated through a fuzzy logic control system.

2. Truck Platooning Technologies

An overview, from local to global level technologies that enable truck platooning is illustrated. On a local level, technologies within a small range of the vehicle are effective, such as Cruise Control (CC) and Adaptive Cruise Control (ACC). The ACC system is an extension on the CC system and was previously illustrated as a means to enable vehicle platooning [2]. The system that takes over the throttle of that vehicle to maintain a steady speed as set by the driver is known as Cruise Control system. The throttle valve controls the power and speed of the engine by limiting the amount of air intakes and is actuated automatically, instead of by pressing a pedal, when the cruise control system is engaged [2][3]. The Adaptive Cruise Control system is an extension of the CC system, which adjusts the vehicle speed automatically so as to maintain a safe distance from the vehicles ahead. ACC uses either radar or laser sensors to detect the speed of and distance to the vehicle ahead. If the distance to a vehicle or object ahead diminishes, the system will send a signal of decelerating the vehicles to the engine or braking system and the other way around for increasing distance [5][4]. An extension on the ACC system is Cooperative ACC (CACC), which uses longitudinal automated vehicle control by accounting for road information, such as road grade, and traffic events occurring further in the platoon, such as traffic congestion. This can be obtained through wireless communication in short and wide range relative to the vehicle, by Vehicle to Vehicle (V2V) communication and Vehicle to Infrastructure (V2I) technology, respectively [6] . The interaction between vehicles is enabled through V2V communication and thus, can improve safety. By combining Global Positioning Systems (GPS) and V2V technology, the relative position estimates of neighboring vehicles can be derived with high accuracy. Hence, smoother control can be implemented through prediction based upon the gathered information, enabling cooperative driving and ensuring automated vehicle platoons [13] . On global level, implementation of routing and road information is allowed through V2I technology[5]. A command center or fleet

ISSN 2356-5608

manager can monitor the vehicles in real-time traffic through V2I, enabling the possibility to react on road and traffic information and maximized the transport mission and thereby the vehicle's fuel consumption. For example, fuel consumption can be reduced by adjusting the vehicle speed to form a platoon. Furthermore, an alternative path can be found through V2I to ensure the arrival deadline of the transport mission when obstructing traffic situations are encountered [8]. Technologies such as V2V and V2I are part of Intelligent Transport Systems and services (ITS), where ITS denotes the integration of Information and Communication Technology (ICT) with transport infrastructure, vehicles and users [6][7]. ITS in trucks includes all types of communication in and between vehicles (V2V communication) along with communication between vehicles and infrastructure (V2I communication). With the aid of these communication devices, a cooperative system is obtained for supporting and replacing human functions in various driving processes with a view to enhancing operational performance, mobility, environmental benefits, and safety. [11].

3. FUEL CONSUMPTION MODEL

to understand the effect of communication setup on performance of the platoon followers, a simplified fuel consumption model is applied to estimate instantaneous fuel usage[14].

$$f = \frac{\int_{t0}^{tf} \delta\left[\left(\mu\cos\theta + \sin\theta\right)Mgv + kv^3 + Mav\right]dt}{H\eta} ......(1)$$

where t_0 and tf are the initial and final time instances; H *is the energy density* and η is the efficiency; v *is the vehicle speed*and $a$is acceleration; *T*he mass of vehicle is M; δ shows if the engine is active

$$\delta(t) = \begin{cases} 1 \quad if & (\mu\cos\theta+\sin\theta)Mgv+kv^3+Mav) \\ 0 & otherwise \end{cases} ......(2)$$

the air-drag coefficient κ is derived from:

$$k = \frac{1}{2} p_a A_a CD(1-\phi) .....(3)$$

The air-drag reduction φ is illustrated and depending on inter-vehicle distance, vehicle type and vehicle position in platoon. The nth ($n \geq 4$) vehicle in car platoon. The equation for the CO_2 [g/km] emissions at average speed and normal driving dynamics is:

$$CO2 = (465*M + 48.1*P)/v + 32.4*M + 0.89*P$$
$$-\ (0.48*M + 0.0256)*v + (0.000889*M + 0.00041)*v^2 ......(4)$$

v [km/h] is the velocity, M [ton] the total vehicle weight, en P [kW] the rated power.

4. THE DRIVING BEHAVIOR AND CO2 EMISSIONS

Velocity and non uniform (acceleration and deceleration) are the major factors that affect fuel consumption in driving thus leading to the emission of CO2 per kilometer. Based on physical principles - the aerodynamic resistance force keeps increasing quadratically with respect to the velocity. Note that ; the air drag is the most significant part in the CO2 emissions at a speed that is greater than 100 km/h. Almost three quarters of power at 100km/h is required to overcome aerodynamic drag . Furthermore, from 100 km/h to 120 km/h, the air drag is increasing at 44% and the required engine power increases approximately by 33%. Smaller engines often required higher speeds to drive at this particular velocity, thus fuel consumption is very high. Big engines with large power reserves, means that the extra fuel consumption is possibly lower. Since trucks are incorporated with speed limiters, trucks do not drive faster than the average velocity of 90 km/h. Furthermore, the air drag has a lower portion in the total power demand, because the mass and the inertia is higher [14]. Therefore, the effect of an increased velocity is smaller. The increase in CO2 emissions is almost 12% beween 80 km/h and 90 km/h since air drag is about half of the total power demand. The above rules of thumb are based on differences in constant driving speeds, assuming all other conditions remain constant. The influence of weight is therefore minimized, and is pertinent in the rolling resistance. The basic rule for the rolling resistance is almost 16 to 20 g/km of CO2 emissions per ton of vehicle weight for all vehicles. New heavier vehicles that uses diesel engines are closer to the minimum number but small older vehicles utilizing petrol engines are closer to the maximum number[15]. Total CO2 emissions are higher per kilometer for heavy vehicles but partly lower per unit weight. Different driving behaviors are not included in the claimed effect. Therefore, congestion produces the highest CO2 emission per kilometer, which is the outcome of combining two effects: (1) The large amount of braking which dissipates the kinetic energy of the vehicle to heat energy. This contributes about one- third of the total CO2 emission in congestion,

(2) the losses from the engine play a major role at the lower velocity, due to the fact that the time at which the engine is operating is responsible for the engine losses, and at 15 km/h in congestion, the engine is working four minutes for each driven kilometer. This accounts for almost 100 grams of CO2 for the normal passenger car and about 400 grams per kilometer of truck. The driving behavior that was used for determining the emission factors is dependent on measurements from the road. [16].

TABLE 1: Parameters and observable variables affecting behavior.[10]

no	Parameters	Measurable variables
1	Experience	1. Number of Km per year
		2. Number of years with driving license
2	Attitudes	1. Speed choice
		2. Lane keeping
		3. Overtaking propensity
		4. Headway
3	Task demand	1. Traffic complexity
		2. Weather
		3. Light
		4. Speed
		5. Driving direction
4	Driver state	Lane keeping; headway control
		2. Driving duration; time-on-task
		3. Weather, road conditions
		4. Traffic complexity
5	Situation awareness	5. Speed
		1. Distraction
		2. Driver state
		3. Task demand

ISSN 2356-5608

5. OVERVIEW FUZZY LOGIC SYSTEM

Fuzzy logic has found importance in engineering fields as it incorporates imprecision and subjectivity into the model formulation and solution process. It attains even more importance when used to model systems that are hard to define precisely, such as supplier evaluation in SCM. Due to this distinct property of fuzzy logic, it has been able to aid research in production management when the dynamics of the environment limits the specification of model objectives, constraints[12].The truth value of a variable (in a classification problem) for a fuzzy logic is a real number between 0 and 1. To achieve adequate truck platooning, we must integrate aspects of human intelligence and behaviors so that trucks can manage driving actuators in a way similar to humans. Fuzzy Logic resembles the human being decision-making methodology. It deals with vague and imprecise information which is gross oversimplification of the problems in real world and based on the degrees of truth. An observation ofthe diagrams below shows that in fuzzy logic, the values are represented by number which ranges from 0 to 1. Hence, 1.0 indicates absolute truth whereas 0.0 denotes absolute false. Truth value is the number that denotes the value in fuzzy system.

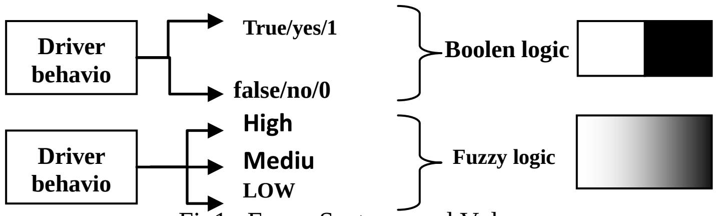


Fig1. Fuzzy Systems and Values

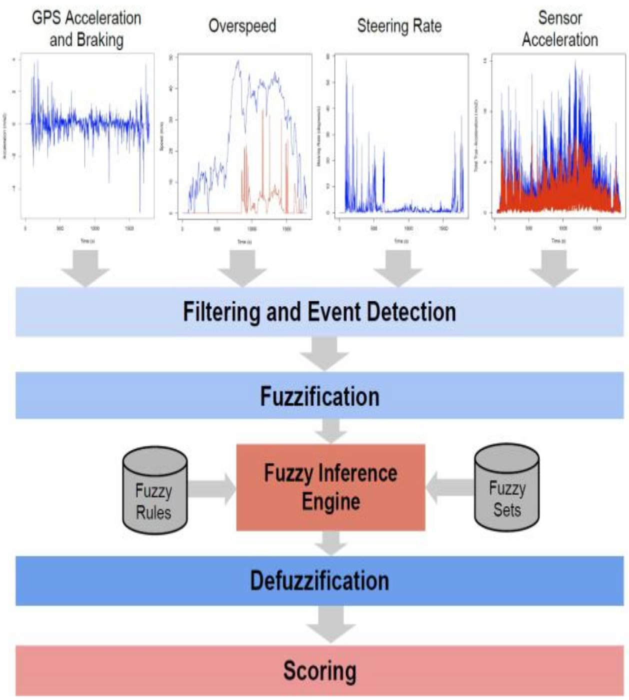
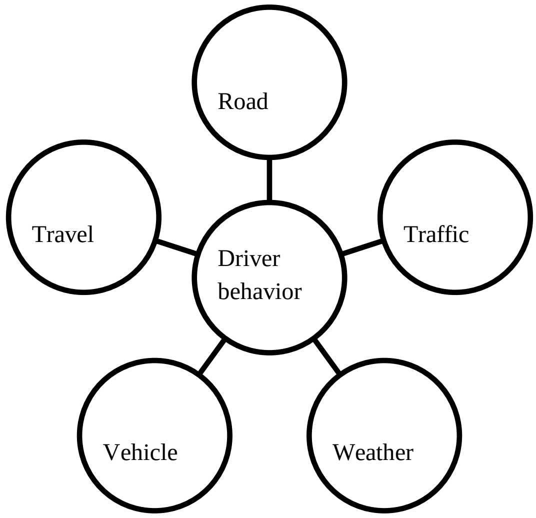


Fig2fuzzylogic system [13]

6. TRUCK LEADER DRIVER BEHAVIOR

the driver can play an important role in the CO2 emission by its vehicle use and driving style. Driving behavior differs among drivers. Every human driver follows his specific patterns while driving. This fact is observable in ordinary driving behaviors such as hitting the gaslbrake pedals, turning the steering wheel and distance keeping while following a vehicle[10]. In general, Data describing characteristics of driving environments are not available to drivers in precise numerical format. Instead drivers perceive and describe the driving environment in imprecise terms such as “high speed” or “enough space to change lanes”[9]. A significant outcome of imprecision is the possibility of assigning more than one symbolic value at the same time to the same variable with different degrees of truth in each of these values. Because of fuzzy logic’s ability to handle these cases, it has been applied successfully in modeling human behavior in general and driver behavior in particular . The fuzzy logic has proven to be a very effective tool for handling imprecision and uncertainty, which are both very great characteristics of driving environment thus making fuzzy logic a powerful candidate tool in most traffic engineering studies. In many fields of science, including biology, psychology, and so on, human observers have provided linguistic explanations and descriptions of various systems. [11]

.



A structure diagram of the factors affecting for driver behavior

7. CONCLUSION

This paper demonstrated that truck platooning has significant ability to be automated and incorporated into green road freight transport system as a good step towards solving the several challenges which are currently faced by this sector. However, for it to be successful, different stakeholders with diverse interest must come together and cooperate on how it’s going to work effectively. Truck Platoon has many benefits to the society at large such as its application in green road freight transportation without causing the emission of hazardous greenhouse gas on the road and road users. Platoon automation of freight road transport would greatlyreducethe cost of transportation and minimizes the risk of road transport. Platoon is predicted to reduce traffic congestion and improve the safety of the road users even the lead trucks. Fuzzy logic system leader truck platoon and follower regulatory fit to be a novel source of such manoeuvre driver, which was elicited by the lead truck style that arises from a leader truck platooning regulatory focus. Hence, this research provides an explanation for the green drive behaviour of being valued by leader, and has done so by taking into account both leader characteristics and leader behaviour. However, the greatest reduction in drag occurs for the trucks between the first and last truck. It is calculatedthat platoon trucks could gain fuel efficiencies ; the lead truck gains as much as 7% while the trailing truck got up to 15%.It is obvious that the more trucksin the platoon convoy, the better the efficiency because the first and the last don’t garner the full effects of drafting. The model suggests that the trucks should closely follow each other at 3-4 metres so as to maximized the aerodynamic savings. Truck

ISSN 2356-5608

platooning boosts fuel efficiency and also serves as a cornerstone of future sustainable green freight road transport system.

ACKNOWLEDGEMENT

My special thanks to IFSTTAR,UVHC,GIS-GRAISyHM for their assistance towards face-lifting this work.

Reference

[1] S. Tsugawa, S. Kato, and K. Aoki, “An automated truck platoon for energy saving,” IEEE Int. Conf. Intell. Robot. Syst., pp. 4109–4114, 2011.

[2] J. Klauenberg, C. Rudolph, and J. Zajicek, “Potential Users of Electric Mobility in Commercial Transport – Identification and Recommendations,” Transp. Res. Procedia, vol. 16, pp. 202–216, Jan. 2016.

[3] K. Y. Liang et al., “Networked control challenges in collaborative road freight transport,” Eur. J. Control, vol. 30, pp. 2–14, 2016.

[4] C. Bergenhem et al., “Overview of platooning systems,” in Proceedings of the 19th ITS World Congress, Oct 22-26, Vienna, Austria (2012), 2012, pp. 1–7.

[5] C. Bergenhem, E. Hedin, and D. Skarin, “Vehicle-to-Vehicle Communication for a Platooning System,” Procedia - Soc. Behav. Sci., vol. 48, pp. 1222–1233, Jan. 2012.

[6] S. Ahmed, “ICT Integration for Electric Vehicles as Data Collector and Distributor of Data Services,” pp. 3–7, 2015.

[7] S. Suganya and D. Menaka, “International Journal on Recent and Innovation Trends in Computing and Communication Performance Evaluation of Face Recognition Algorithms,” pp. 1–135.

[8] P. C. Baptista, I. L. Azevedo, and T. L. Farias, “Information and Communication Technology Solutions in Transportation Systems: Estimating the Benefits and Environmental Impacts in the Lisbon,” Procedia - Soc. Behav. Sci., vol. 54, pp. 716–725, 2012.

[9] G. Schilk and L. Seemann, “Use of ITS Technologies for Multimodal Transport Operations – River Information Services (RIS) Transport Logistics Services,” Procedia - Soc. Behav. Sci., vol. 48, pp. 622–631, 2012.

[10] A. Khodayari, R. Kazemi, A. Ghaffari, and R. Braunstingl, “Design of an improved fuzzy logic based model for prediction of car following behavior,” Mechatronics (ICM), 2011 IEEE Int. Conf., no. Lv, pp. 200–205, 2011.

[11] S. Ghaemi, S. Khanmohammadi, and M. Tinati, “Driver’s behavior modeling using fuzzy logic,” Math. Probl. Eng., vol. 2010, 2010.

[12] D. Kumar, J. Singh, and O. P. Singh, “A fuzzy logic based decision support system for evaluation of suppliers in supply chain management practices,” Math. Comput. Model., vol. 57, no. 11–12, pp. 2945–2960, 2013.

[13] Meiring, G. A. M., & Myburgh, H. C. (2015). A review of intelligent driving style analysis systems and related artificial intelligence algorithms. *Sensors*, *15*(12), 30653-30682.

[14] Ligterink, N. E., van Zyl, D. I. P., & Heijne, V. A. M. (2016). Dutch CO2 emission factors for road vehicles (No. TNO 2016 R10449). TNO.

[15] Kuiper, E., & Ligterink, N. E. (2013).Voertuigcategorieën en gewichten van voertuigcombinaties op de Nederlandse snelweg op basis van assen-combinaties en as-lasten. TNO report TNO, 12138.

[16] Lange, R. D., Eijk, A., Kraan, T., Stelwagen, U., & Hensema, A. (2011). Emissiefactoren voor licht wegverkeer bij maximum snelheid van 130 km/u op autosnelwegen (No. TNO-060-DTM-2011-03219). TNO.

ISSN 2356-5608